Application No. 10/613,259
Amendment dated: December 14, 2004

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of the claims in the application:

Listing of Claims:

1. (currently amended) An optical amplifier for a wavelength switched optical network comprising:

a Raman module for amplifying a WDM optical signal with a Raman gain;

an EDFA module connected to said Raman module for further amplifying said WDM signal with a EDFA gain; and

a shelf-level control network for monitoring and controlling operation of said optical amplifier to maintain a substantially similar power for all channels of said WDM signal, said shelf level control network including an amplifier controller for determining a maximum provisioned Raman gain value and reducing the Raman gain from the determined maximum provisioned Raman gain value to a flexed gain value while keeping the EDFA gain unchanged.

2. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 1, wherein said shelf level network comprises:

~~an~~ a shelf processor for determining a gain target for said optical amplifier based on current performance, topology and connectivity data concerning said wavelength switched network; and

an embedded controller on each card-pack of said modules for dynamically adjusting ~~respectively~~ said Raman gain and ~~said~~ setting EDFA gain according to said target gain.

3. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 2, wherein said embedded controller comprises:

a bridge for distributing and collecting an optical trace signal provided between a host card-pack and all card-packs physically connected to said host card-pack;

an interface for connecting said embedded controller with said shelf processor; and

a microprocessor for controlling operation of optical components on said host card-pack.

4. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 2, wherein said EDFA module has a first and a second stage with a mid-stage access between said first and second stage.

5. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 4, wherein said embedded controller of said EDFA module comprises a gain control loop which operates each of said stages according to a gain target.

6. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 2, wherein said Raman module comprises at least two Raman pumps.

7. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim [[8]]6, wherein said embedded controller of said Raman module changes the ratio between the power of said Raman pumps for optimizing OSNR performance of said optical amplifier.

8. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 2, wherein said embedded controller of said Raman module sets said Raman gain to an optimized value based on a attainable maximum Raman gain and the loss of the fiber span upstream from said optical amplifier.

9. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 1, further comprising a multi-port optical spectrum analyzer module for measuring power and spectrum of said WDM signal in a plurality of measurement points provided on said optical amplifier and transmitting the measurements to said shelf processor over said shelf-level control network.

10. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 4, further comprising a gain flattening module connected between the stages of said EDFA module to flatten-out the power of specific channels.

11. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 4, further comprising a dispersion compensating module DCM connected between the stages of said EDFA module, said DCM including a compensator with a net dispersion value and slope selected according to a link target.

12. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 2, wherein said shelf processor receives identification data from all card packs of said optical amplifier

over said shelf-level control network and communicates shelf identity and presence data to a network services controller over a site-level control network.

13. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 12, wherein, whenever a fiber span preceding said optical amplifier has a low loss, said network services controller operates said Raman pump monitor to maintain a constant net gain.

14. (currently amended) ~~An~~ The optical amplifier ~~as claimed in~~ of claim 4, further comprising a variable optical attenuator connected between said first and said second stages.

15. (cancelled)

16. (cancelled)

17. (cancelled)

18. (cancelled)

19. (currently amended) A line monitoring and control system for a line amplification system of a wavelength switched optical network, the line amplification system including at least one Raman amplifier and at least one EDFA amplifier, the control system comprising:

an embedded control layer, comprising an embedded controller provided on each card pack of an optical amplifier for controlling operation of said card pack;

a link control layer comprising a plurality of shelf processors for coordinating operation of all optical amplifiers connected on a link of said wavelength switched optical network to achieve an output power profile target for said link, wherein the Raman amplifier is adjusted to that its Raman gain value is adjusted from a determined maximum provisioned Raman gain value to a flexed gain value while keeping the EDFA gain unchanged; and

a network control layer comprising a plurality of optical link controllers for coordinating operation of all optical modules placed on a plurality of consecutive links making-up a connection.

20. (currently amended) [[A]] The line monitoring and control system ~~as claimed in~~ of claim 19, wherein said embedded controllers of all card-packs of an optical amplifier placed in a shelf are connected with an associated shelf processor of said plurality of shelf processors over a shelf LAN.

21. (currently amended) [[A]] The line monitoring and control system ~~as claimed in~~ of claim 19, wherein said shelf processors of all optical amplifiers connected along said link are connected with an associated optical link controller of said plurality of optical link controllers over a link LAN, said optical link controller for at least commissioning and certifying said link and testing link quality parameters.

22. (currently amended) [[A]] The line monitoring and control system ~~as claimed in~~ of claim 19, wherein said optical link controllers of all optical units along an optical path are connected with an associated network connection controller NCC over a path LAN, said NCC for setting-up, tearing-down and controlling said connection.

23. (currently amended) [[A]] The line monitoring and control system ~~as claimed in~~ of claim 19, wherein said embedded controllers and said associated shelf processor distinguish between operation of said optical amplifier in a normal mode, a power railing mode and a failure mode, for allowing operation at a gain target value above a specified maximum gain value, on demand.

24. (currently amended) ~~An optical amplifier as claimed in~~ The line monitoring and control system of claim 23, wherein said link control layer increases said gain target of a downstream amplifier of said line amplification system whenever an amplifier operates in said power railing mode.

25. (cancelled)

26. (previously cancelled)

27. (previously cancelled)

28. (previously cancelled)

29. (previously cancelled)

30. (previously cancelled)

31. (previously cancelled)

32. (previously cancelled)

33. (previously cancelled)

34. (previously cancelled)

35. (currently amended) A method of transmitting a WDM signal along a span of a wavelength switched optical network comprising:

measuring an input power of said WDM signal at the input of said span;

amplifying said WDM optical signal with both an EDFA gain and with a Raman gain, the amplification with the Raman gain including determining a maximum provisioned Raman gain value and reducing the Raman gain from the determined maximum provisioned Raman gain value to a flexed gain value while keeping the EDFA gain unchanged, and measuring the spectrum and output power of said WDM signal; and

controlling operation of said optical amplifier according to said input and output power and spectrum and also according to a set of rules to compensate for the losses and degradation of said WDM signal along the fiber of said span.

36. (currently amended) ~~A method as claimed in~~ The method of claim 35, wherein said step of controlling is effected at regular intervals for continuously optimizing transmission along said span in the presence of dynamic configuration and re-configuration of connectivity within said wavelength switched network.

37. (currently amended) ~~A method as claimed in~~ The method of claim 35, wherein said step of ~~amplifying comprises amplifying said WDM signal with a Raman gain, further amplifying said WDM signal with an EDFA gain and~~ flattening the spectrum of said WDM signal with gain flattening means.

38. (currently amended) ~~A method as claimed in~~ The method of claim 37, wherein said step of amplifying said WDM signal with a Raman gain further comprises:

determining a the maximum provisioned Raman gain value G_raman_max, where a loss parameter is acceptable for a set of channels of said WDM signal;

reducing said Raman gain from said maximum gain value to a flexed gain value G_raman=G_raman_max-(Mean_span_- loss-Actual_span), while keeping said EDFA gain unchanged, for enhancing said loss parameter of under-performing channels of said WDM signal; and

pumping light along said span to obtain said G_raman.

39. (currently amended) ~~A method as claimed in~~ The method of claim 38, further comprising providing an offset and adjusting said flexed gain to G_raman=G_raman_max-(Mean (Mean_span_loss-Actual_span)+Offset.

40. (currently amended) ~~A method as claimed in~~ The method of claim 37, wherein the Mean_span_loss is selected for a large range of fiber types.

41. (currently amended) ~~A method as claimed in~~ The method of claim 38, wherein said step of determining comprises:

during network commissioning, determining maximum provisioned Raman gain for a link to which said span belongs;

setting-up all said Raman gain for each optical amplifier along said link to said respective maximum provisioned Raman gain value;

noise loading said link until a measurable Q/BER value is achieved at the output of said link; and

adjusting said maximum provisioned Raman gain value of each said optical amplifier until an optimum Q is achieved for said link.

42. (currently amended) ~~A method as claimed in~~ The method of claim 41 further comprising tilting said Raman gain to equalize and minimize a noise parameter for all channels in said WDM signal.

43. (currently amended) ~~A method as claimed in~~ The method of claim 42, wherein said step of tilting comprises changing the ratio of the power provided by the pumps of each said respective pump unit.

44. (currently amended) ~~A method as claimed in~~ The method of claim 38, wherein said step of amplifying comprises:

setting said Raman gain at a level above a maximum provisioned gain; and

reducing said EDFA gain for a set of blue channels at the border of the L-band for obtaining a reduced spectrum for said optical amplifier to allow operation of said wavelength switched optical network in both C-band and L-band.

45. (currently amended) ~~A method as claimed in~~ The method of claim 44, further comprising specifically attenuating said set of blue channels using gain flattening means.

46. (currently amended) ~~A method as claimed in~~ The method of claim 37, wherein said controlling operation comprises:

receiving a current target performance parameter for said optical amplifier determined based on the current and previous end-to-end performance of said WDM signal and updating said set of rules;

determining a control signal based on said current target performance parameter;

distributing said control signal between said modules based on a model of said optical amplifier to control individually operation of each said module.

47. (currently amended) ~~A method as claimed in~~ The method of claim 46, wherein said controlling operation further comprises compensating for small gain non-uniformities using a gain flattening module connected in the mid-stage of said EDFA module.

48. (currently amended) ~~A method as claimed in~~ The method of claim 46, wherein said target performance parameter is an output gain profile for said WDM signal, comprising a gain target component for each channel of said WDM signal.

49. (currently amended) ~~A method as claimed in~~ The method of claim 46, wherein said target performance parameter comprises a Raman gain target and an EDFA gain target.

50. (currently amended) ~~A method as claimed in~~ The method of claim 46, wherein said controlling operation comprises increasing the output power of said optical amplifier above a specified maxim but under a safety margin, without causing amplifier alarm, to take advantage of the available output power distribution above said specified maxim.

51. (currently amended) ~~A method as claimed in~~ The method of claim 46, wherein said controlling operation comprises connecting a dispersion compensating module DCM as a mid-stage in said EDFA module, and adjusting same to a net dispersion value and slope selected according to a link dispersion target.

52. (currently amended) ~~A method as claimed in~~ The method of claim 46, wherein said controlling operation comprises, for a short span, decreasing said input power while maintaining said Raman gain at said target Raman gain for maximizing the OSNR of said short span.

53. (currently amended) ~~A method as claimed in~~ The method of claim 35, wherein measuring the spectrum of said WDM signal is performed with a multi-port optical spectrum analyzer module connected to one or more measurement points.

54. (currently amended) ~~A method as claimed in~~ The method of claim 35, wherein said controlling operation comprises:

providing each said module of said optical amplifier with an optical widget controller OWC;

connecting said OWCs over a LAN for exchanging operation, administration, maintenance and provisioning (OAMP) information with an optical group controller OGC;

at said OGC, calculating an individual gain target for each module of each said optical amplifier and a gain target component for each channel of said WDM signal passing through said optical amplifier; and

at said OWC, controlling the power of each channel of said WDM signal according to said gain target component.